ENERGY-ABSORBING FLOOR-ASSEMBLY OF MOTOR VEHICLE

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part application of co-pending international application number PCT/DE 97/00715 (WO 97/39937), filed Sept. 4, 1997 and claiming the priority of German Patent Doc. DE 19615985 C1, filed April 22, 1996. The symbol "C" of DE 19615985 "C"1 indicates a German Patent and "B" an European Patent such as European Patent Doc EP 0844939 "B"1. Contrarily, the symbol "A" indicates a German and European Pending Patent such as DE 4224489 "A"1 and EP 0565501 "A"1.
German and European Pat. Appls. or Docs., which will be omitted, are designated by the abbreviations "DE" and "EP" hereinafter.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates generally to an energy-absorbing vehicle floor of motor vehicle, more particularly, to the large area (region) between the front pillars (post sections or pillar portions) and the rear bumper, which is exploited to accommodate at least one deformable element. This deformable element is equipped with at least one pair of independently operating piston devices, in which a pair of springs is installed,

- to store minor energy when the bumper is loaded and to return the bumper back, when unloaded, to the home position, and
- to absorb (dissipate) large (major) impact energy in the event of arbitrary collision (front-, side- or rear collision) or pile up (mass accident).

Other objects disclose a deformable floor of a trunk compartment in the front or rear section of vehicle body, wherefrom the floor is releasable and detachable. Rooms formed by this upper floor and a lower deformable floor can be used for storage.

2. Description of the Related Art:

It is known in the prior art to construct a vehicle frame for motor vehicle defining the shape of the vehicle, for sustaining various loads and for co-operating with deformable longitudinal runners and/or deformable elements to absorb the impact energy in a real accident. However, the proven deficiencies of this construction [11, 12] are due to the inapplicability or limited applicability of the prior art, which undergoes the examination in the following description and will be improved by the present invention.
For years R&D (Research and Development) work has been focused on developing compact cars suitable for every day driving that help resolve the problems of increasing traffic density, make it easier to park and lower the fuel consumption to under 4 litre for 100 km. These prototypes at the Automotive Salons or Shows were AUDI A2 ®, Opel Maxx ®, MB A-Class ®, MCC Smart ®, Honda Logo ®, VW Lupo ®, Toyota Yaris ® etc. In autumn of 1997 Mercedes Benz was the first car manufacturer to offer a full-sized four-seater compact car of MB A with a baby carriage-sized trunk compartment (storage compartment), illustrated in **Figs.** 2a, 3a.

Serving as deformable elements ref. to DE 4224489 A1, DE 3925990 A1 and DE 3826958 A1 and DE 4342759 C1 both front portions of longitudinal runners in association with the front section of vehicle structure convert the impact energy into deformation work to reduce the acceleration in the event of mid-front collision.

Ref. to DE 3826958 A1 the rear section of front portion of each longitudinal runner, in abutting relationship to the passenger compartment (cell), has the greatest stiffness while the deformable front section, whereto an auxiliary deformable element having variable cross section in longitudinal direction is fastened, has variable stiffness in longitudinal direction for the purpose of controlling the rate of acceleration and determining the start of pre-tensioning the belts in mid-front collision.

A safety device ref. to DE-OS 2121464 discloses a brake system which should able to decelerate at 60 m/s^2 in order to pre-tension the seat belts within 8 ms, noted in to DE 3826958 A1. Based on the brake-deceleration of 9.9 m/s^2 for VW Passat ® [7], 8.4 m/s^2 for VW Polo ® [8] at the speed of 100 km/h, the linear equation $t = v/b$ yields a brake-time of 2.8 s and 3.3 s. In 60 ms the curve converges towards zero. Accordingly, the safety device with a 50-times power of brake-deceleration would be complex to construct, hence, expensive.
Another safety device includes a common cross member laterally attached to the middle of the vehicle floor and connected to four rods of the front bumper, provided with four coil springs, and to three rods of the front bumper, provided with three coil springs. This safety device, suited for storing energy, is incapable of absorbing impact energy.

Ref. to DE 4224489 A1 extrusion components used for the front portions of longitudinal runners are fabricated from light materials such as aluminium, magnesium or alloys thereof. In dependence on the following cross sections 4-, 6-, 8-edges, 4-edges with strut, round profile with strut the mass-dependent energy absorption and the buckling force were surveyed. The result thereof has encouraged the assignee AUDI Corp. to assemble a pair of extrusion components in AUDI A8 ®. Unfortunately, due to lack of sites of predetermined fracture those components under load are subjected to lateral buckling. Responsive to that deficiency the front and/or rear portions of longitudinal runners, made of light materials, ref. to US 5,480,189 are provided with sites of predetermined fracture. However, the energy-absorbing device does not work in the event of offset, inclined front or rear collision, illustrated in **Figs.** 39 to 43.

As exemplified in DE 3925990 A1, each pair of energy-absorbing front and rear portions of longitudinal runners is supported by a pair of energy-absorbing devices in order to prevent lateral buckling thereof in the event of mid-front or mid-rear collision. From all exemplary teachings of the prior art this is the most promising invention thanks to the following features:

1. During the deformation in a mid-front collision both energy-absorbing subframes (spring domes) move downward and underneath the passenger compartment which is subjected to less acceleration thus lowering injury severities.
2. The device including three pairs of energy-absorbing deformable elements achieves the largest amount of energy absorption.

Unfortunately, these voluminous pairs, suited for MB S, cannot be accommodated in a compact, small- and mid-size car. Responsive to that deficiency a large force resulting form a mid-front collision is absorbed by a pair of energy-absorbing front portions of longitudinal runners that co-operate with a pair of C-shaped energy-absorbing members of subframes of MB C, ref. to DE 4342759 C1, in abutting relationship to the passenger compartment subjected, unavoidably, to the remaining load. Moreover, the collapse of the passenger compartment of MB C200 [11] in a real accident, illustrated in **Fig.** 43, documents the failure of the prior art.

Due to the uniform displacement of the power train (drive train) ref. to DE 3301708 C2 and DE 4405904 C1 in the event of mid-front collision only minor energy can be absorbed by a deformable element arranged therebehind and attached to the tunnel.

Ref. to DE 4406129 A1 a front mechanism **200** comprises the front bumper **35**, two connecting rods **208**, a cross member **210** and an energy-absorbing panel **216** installed in the rear section of vehicle structure. A rear mechanism **201** comprises the rear bumper **36**, two connecting rods **209**, a cross member **211** and an energy-absorbing panel **215** installed in the crumpling section of the vehicle structure. Each panel **215, 216** is interposed between the respective bumper and cross member arranged outside of the passenger compartment **203** defined by the dotted lines shown in **Fig.** 34. In the event of mid-front or mid-rear collision the connecting rods **208** or **209** can move, only in parallel relationship to each other, in the channels **212** (**Fig.** 35) to push the cross member **210** or **211** deforming the energy-absorbing panel **216** or **215**.
Unavoidably, the rotation (yaw-angle) of the vehicle about the high axis of the centre of gravity of the vehicle in arbitrary front collision will be increased due to the position of the cross member behind the centre of gravity of the vehicle and to the rigid connection of both rods to each other (**Figs.** 40, 42, 43)

As exemplified in **Figs.** 36 to 38 of DE-OS 2225481, a safety device **220** comprises two girders **231, 232** pivotally connected to each other by a joint **223**, a suspension system [1 to 3] consisting of a coil spring **225** and shock absorber **226** in force-locking connection with two girders **241, 242**. This safety device, pivotally connected to two bearings **221, 222** of front and rear axle, is subjected to the following load cases in compliance with Technical Mechanics:
*Load case I in the z-y plane (**Fig.** 36):* The moment $M_x = H*h$ about the x-axis is replaced by a pair of forces $H_A = (H*h)/l$ with the lever arm of the length l. From the equilibrium condition for moments two forces of reaction are obtained: $V_A = (V*l_C)/l$ and $V_B = -V_A + V$. These three forces in z-direction $-V$, $(H_A + V_A)$ and $-(H_A + V_B)$ exert the bending moment M_{zy} along the y-axis imposed on the safety device.
*Load case II in the z-x plane (**Fig.** 37)*: The force V exerts the bending moment $M_{zx} = V*b$ imposed on the safety device along the y-axis.
*Load case III in the x-y plane (**Fig.** 38)*: The safety device is subjected to the bending moment $M_{xy} = -H*b$ along the x-axis and buckling force H.
The bending moments M_{zx}, M_{xy}, M_{zy} and buckling force H yield the total stress which is in contradiction to the compressive or tension stress, noted in DE-OS 2225481.

In co-operation with a pair of dependently operating piston devices assembled in the front portions **30.1** of both runners ref. to US 3,860,258, FR 2181044 A and GB 2169377 A, the respective features of energy absorption
- contradict the concept of compact car limited by an extremely short front section of the vehicle body e.g. approx. 50 cm of MB A
- fail to absorb energy in the event of offset or inclined front collision (**Figs.** 39, 41, 43) because both piston devices can only operate in dependent relationship to each other and
- increase the rotation of the vehicle about the vertical axis thus yaw-accelerating the heads of restrained passengers. In the event of 40 % offset Euro-NCAP (European New Car Assessment Programme) test [9] the vehicle VW Golf IV, driven at 64 km against a deformable barrier, rotates about 80^0, substantially more than the yaw angle of the similar vehicle in a 50 % offset crash against a stiff barrier (**Figs.** 40, 42).

Ref. to US 3,860,258 the similar corrugated portions (zones) of the longitudinal runners and side rails should control the rate of acceleration in mid-front collision. Due to the constant stiffness thereof a single rate of acceleration will be achieved abruptly and immediately. Obviously, the corrugated zones weaken the overall stiffness of the vehicle frame which will collapse in side collision.
Furthermore, the operation of telescoping bumper is restricted because the pair of telescopic energy absorbers can work only in mid-front collision.

By applying the Newton law "action = reaction" the pair of hydraulic piston devices ref. to GB 2169377 A proposed for energy absorption would be as bulky and expensive as the $ 10 millions hydraulic device of Carl Schenck or Mannesmann Corp. which builds up the energy to accelerate a vehicle in a crash test.

Ref. to FR 1181569 and DE-OS 2211976 a pair of shock absorbers is rigidly connected to the front bumper and a cross bar of the vehicle frame to store minor energy resulting from the mid-front collision of the car, when parking, against a hindrance and upon the release of the stored energy to return the bumper to the home position when the car is reversed.

In comparison with a small car VW Polo ® with length x height x width = 3.71 x 1.42 x 1.66 m compact cars have a shorter length such as MB A with 3.58 x 1.56 x 1.72 m and Opel Maxx ® with 2.97 x 1.58 x 1.58 m. In spite of airbags, belt pre-tensioners and reinforcing elements, the larger, stiffer vehicle structure of conventional cars and vans cannot always ensure survival chance in real accidents [11, 12]. Conceivably, the very small size of compact cars reflects the strenuous R&D work to resolve the problems of energy absorption in the event of front-, rear- or side collision. Furthermore, the following goals are at cross-purposes. Those specifications of crash tests are usually met by a complex, costly design to enhance the survival chance at extremely low manufacturing costs.

The current development of compact cars and small-size vehicles is attributed to the following teachings of the latest prior art regarding passenger protection and manufacturing method:

Extrusion components fabricated from light materials are used for the supporting members of the vehicle door, frame, cross members, side rails and pillars ref. to DE 4335043 A1. A vehicle floor and door are assembled by plug-in connecting the engaging pieces of each member into the mating profiles, sockets and/or holes of the other and by glueing them. The high manufacturing costs are partly compensated by the relatively inexpensive, simple methods of assembly and preserving the tolerance zones, however, not sufficiently enough to justify serial production. Presumably, the problems of energy absorption remain unsolved.

Ref. to US 5,911,426 and 5,921,578 a small shock-dispersing plate **606** and a pair of deformable portions of leading arms **603** of a battery-driven compact car Honda, shown in **Fig.** 44, have energy absorption, far less than that front portions of the pair conventional runners of the compact car MB A ref. to US 5,492,193 that co-operate with the undermentioned deformable element **56** ref. to DE 4326269 C1, shown in **Figs.** 2a, 3a .
In mid-front collision both deformable portions of leading arms are outwardly deformed thereby outwardly displacing both wheels out of interference with the respective side rails.

However, in an arbitrary front collision, shown in **Fig.** 43, only one of the deformable portions of leading arms will be deformed to a limited extent due to the interference of the corresponding wheel with the cross member thereby transmitting the remaining energy to the vehicle frame and increasing the rotation of the vehicle.
In a worst case the left front tire hits the curbstone **611** of a pavement when parking the contact force deforms the deformable portion of left leading arm **603**, shown in **Fig.** 45. How many rims, wheels and suspension systems of the vehicles have been damaged when parking?

The shortcomings of the above-mentioned prior art become apparent in the following front collisions:

- In a 50 % offset crash test, shown in **Figs.** 39, 40 [6], two similar cars MB 230s, rotate at yaw angle "A" = 40^0 about the vertical axis of the mutual point of collision away from the mutual collision line thus exposing the occupants to neck injuries associated with large yaw-acceleration. The need for independently operating piston devices of the present invention is substantiated by the failure to absorb the remaining energy, which forcefully opens the trunk cover **601** of each car.
- In an approx. 50 % offset crash test, shown in **Figs.** 41, 42 [10], a 1480 kg heavy VW Passat **700a**, moving forward to 1 metre, rotates at yaw angle "D" = 35^0, while a 1107 kg heavy VW Polo **600a**, thrown backward to 5 metre, rotates at yaw angle "A" = 45^0 thus backward, rotatably (yaw-) accelerating the heads of restrained dummies of VW Polo.
- The passenger compartment of a two-years old MB C200 **700b** is collapsed to approx. 40 % of its original size by a eight-years old VW Passat **600b** crushing into it at an angle "A_c" = 35^0, shown in **Fig.** 43 [11], resulting in a fatality of the MB C200 driver and severely injured passengers of VW Passat. This accident, outside of the city Idstein, demonstrates the failure of passenger protection of one of the safest cars. It should be clearly understood that Porsche-, MB- and Volvo cars are reputed to be the safest cars in the world and ensure a far better survival chance than other cars in real accidents, as documented in [12].

With the exception of DE 4326269 C1, the deformable elements of the prior art don't fit in a compact car, small- and mid-size car. Ref. to DE 4326269 C1 a deformable element **56** of MB A (**Figs.** 2a, 3a) consisting of honeycomb-shaped energy-absorbing members is in form-locking connection to the front portions **50.1** of longitudinal runners and detachable therefrom. Due to the small size (area) the deformable element is incapable of absorbing large impact energy.

The feature of four stiff impact elements **55a to 55d** (**Figs.** 2a, 3a) ref. to US 5,464,266 (DE 4326270 A1) for energy absorption in side collision is not appropriate. These stiff elements, incapable of absorbing energy, transmit energy from one vehicle side to the other and to the passengers. In the worst case, the residual lateral force rolls the MB A over due to the high centre of gravity of the vehicle. Such stiff elements were already proposed by Volvo Corp. in EP 0565501 A1 disclosing five stiff cross members to transmit energy into the floor. In a side crash test according to FMVSS 214 a 12 litre side airbag cushioning the head lowers the acceleration of chest by 14% while increasing the acceleration of pelvis by 4% despite the five stiff cross members and the side airbag. Passengers are exposed to higher injury severities because the test data are two-times higher than that in a front crash test, described in EP 0844939 B1 (DE 19530219 A1, US 09/210,420) disclosing the side-airbag substitutes superior to expensive, unreliable side airbags. Of all real collision types

the highest rate of severe and fatal injuries is discovered in real side collisions due to the lack of crumpling (crush) section and the medical thesis, that the neck muscle and vertebrae in the lateral direction are weaker than in the longitudinal direction [12].

None of the above-mentioned configurations offer the simplicity of the present invention in

- arranging the large deformable element, whose area is more than **four times** as big as the area of the element **56**, between the front pillars and the rear bumper **36** to absorb much larger impact energy;
- arranging a pair of independently operating piston devices in the in the front and/or rear section of the vehicle body to independently deform the large deformable element and
- substantially improving the survival chance of a vehicle, taken as example the compact car MB A (**Figs.** 2a, 3a), by modifications. Responsive to the deficiencies of US 5,464,266 and EP 0565501 A1 the compact car "GO", shown in **Figs.** 2 to 5, is provided with the interengaging assemblies ref. to. EP 0869878 B1 (US 08/860,182) to connect the doors, pillars, side rails and vehicle roof to each other in arbitrary collision, with the impact beams **20, 20a, 20b** and spring elements **21** ref. to DE 4342038 A1 and at least one deformable element **1, 3** (**Figs.** 1, 31 to 33), preferably, a pair of side deformable elements **2, 2a to 2e** (**Figs.** 1 to 6, 15 to 18, 32) in order to define a crumpling section for each vehicle side. The front-end or rear-end of the deformable element **1** and/or deformable element **3** is/are capable of absorbing large impact energy in any front or rear collision.

SUMMARY OF THE INVENTION

Accordingly, the principle object of the present invention is to optimize the crush behaviour of the vehicle floor, more particularly, of an energy-absorbing floor-assembly in order to substantially reduce large accelerations in the event of arbitrary collision.
This principle and other objects of the present invention are accomplished by the following features (proposals):

- a well-defined controllable deformation behaviour of the deformable element to determine the absorption of subenergies, the total amount of which represents the impact energy, in order to yield the highest efficiency of energy absorption during the controllable folding and buckling;
- a large-area deformable element arranged to the vehicle floor and interposed between the front and rear bumper;
- independently operating piston devices in the front and/or rear section of the vehicle body to guide and to independently deform the respective deformable elements, particularly, in the event of arbitrary front or rear collision;
- a pair of springs co-operating with the independently operating piston devices to store minor energy, when the bumper is loaded, and to return the bumper to the home position when the bumper is unloaded;
- space-saving design for the guided piston rod;
- form- and/or force-locking connection of the deformable element with frame members, wheel cases and/or auxiliary parts in order to avoid the lateral buckling;
- form- and/or force-locking connection of the deformable elements with each other by means of interengaging assemblies in order to increase the energy-absorbing masses in any collision and

- detachable and releasable deformable element, serving as an upper floor of the trunk compartment, to cover the storage room for a spare tire, briefcase etc.

thus resolving the shortcomings and deficiencies of the prior art, substantially lowering the deceleration rate and exploiting the advantages of the energy-absorbing features in a useful construction.

In order to formulate in single terminology a generalized definition for the proper term is presented:

Definition:	**Proper Term:**
"*vehicle floor between the A- or front pillars and the rear bumper*"	a part of the vehicle floor regionally restricted by both A- or front pillars, the rear bumper and both side rails.
"*frame member*" **30 to 34** of a vehicle frame	any longitudinal runner, cross member, tunnel rail or side rail (sill portion)
"*deformable element*" **1, 2, 3** for energy absorption	any energy-absorbing element to convert the impact energy into work of deformation
"*deformable members*"	members of a deformable element
"*auxiliary part*" of a deformable element	auxiliary tube, plate or element for the purposes of guiding and/or fastening a deformable element to the vehicle floor
"*arbitrary collision*"	front, side or rear collision in arbitrary direction of impact force e.g. **Y** at the arbitrary angle "β" or at angle "A_c" (**Figs.** 2, 43)
"*arbitrary front collision*"	front collision in arbitrary offset or arbitrary offset front collision
"*acceleration*"	impact acceleration or deceleration of vehicle during an arbitrary collision
"*stiffness*" of a deformation- or an auxiliary element	stiffness matrix of an element in the direction of impact force **X, Y** or **X1 (Fig.** 31); See FEM-books
"*site of predetermined fracture*"	recess, hole, oblong hole, cut-off, corrugation or crack
"*predetermined site*"	welding spot, engaging point or assembling point
"*engaging part*" of an interengaging assembly	engaging screw, bolt, pin, rivet, block or element
"*mating receptacle*" of an interengaging assembly	mating hole, recess, oblong hole or cut-off
"*energy absorption*"	energy is absorbed by a deformable element upon the release of stored energy when the sites of predetermined fracture are broken

Summary of the advantages of the present invention:

I. The independently operating piston devices comprising parts **5, 5.1, 1.2** and coil springs **4c, 4d** independently deform the respective sections of deformable element **1** (**Figs.** 1, 10, 31 to 33) in the event of arbitrary front or rear collision and independently telescope to store minor energy when the bumper is loaded and to return the bumper to the home position when the bumper is unloaded.

II. Decrease of the amplitude, increase of the eigen-frequency of torsional oscillation, increase of the stiffness of the vehicle frame, reduction of vehicle-weight and substantial deceleration in the event of arbitrary collision by

- arbitrarily attaching a single large-area deformable element **1** (**Figs.** 31, 33) or a number of deformable elements **1, 2, 3, 3a to 3c** (**Figs.** 1 to 4, 15 to 22, 32) to the very large area of vehicle floor between the front or A-pillars and the rear bumper thus solving the deficiencies of the above-listed prior art;
- increasing the energy-absorbing masses by means of interengaging assemblies to connect the deformable elements to each other (**Figs.** 15 to 18, 32), one of which is proposed for energy absorption in front or rear collision and the other for side collision. This overall proposal for energy absorption in any accident is superior to the two individual energy-absorbing systems ref. to US 5,464,266, US 5,492,193 and DE 4326269 C1, above-mentioned, suited for energy absorption in mid-front collision or for energy transmission in side collision;
- increasing the energy-absorbing masses via maximizing the height "h2" of the side deformable element **2a** (**Fig.** 6) and deformable element **2a1, 2a2** incorporated with deformable element **2z** (**Fig.** 23). The height "h2" (**Fig.** 6) is determined by the difference between the vehicle floor **57** and road level "h_B" (**Fig.** 3) serving as clearance for the vehicle floor to the road surface or between both vehicle floors **57** and **57a** of the compact car "AC"; and
- force-locking connection of the auxiliary tubes **60b, 60c, 60c1, 60c2** and/or deformable elements with the frame members.

III. In form-locking connection with frame members and wheel cases, illustrated **Figs.** 1 to 2, 19 to 22, the deformable element **3, 3a** absorbs energy in arbitrary rear or side collision and acts as a releasable floor of the trunk compartment used to cover the storage rooms and to protect the items therein from theft. This feature is applicable too for a trunk compartment in the front section of the vehicle body.

IV. Minor or no impact force imposed on the passenger compartment thanks to control rate of deceleration upon the release of subenergies, the total amount of which represents the impact energy, in excess of the threshold value of the sites of predetermined fracture of deformable elements during the controllable folding and buckling.

V. When a vehicle tunnel is needed for housing an exhaust pipe, drive shaft (drive line) etc., the tunnel rail **60, 60d** (**Figs.** 1 to 2, 31, 33) is replaced by auxiliary tubes **60b, 60c, 60c1, 60c2** (**Figs.** 23, 29 to 32), auxiliary plates **31.5, 32.5, 32.6, 33.5** (**Figs.** 24, 32) and/or a pair of tunnel rails **60e** (**Fig.** 32), between which an accommodation space is defined.

VI. Use of the ledge of the side deformable element **2a1 to 2a3 (Figs.** 6, 23, 32) for

- step rail **2.8** facilitating (disabled) occupants to comfortably step in and out due to the high side rail of compact car, van and small bus and/or
- side bumper of element **2a3 (Fig.** 32) with or without the deformable impact beam **20b (Fig.** 5) to directly absorb impact energy.

Like the front section of the vehicle structure each lateral crumpling section comprises a side bumper and a pair of deformable elements.

VII. Honeycomb-shaped deformable elements serve as a means to dampen road noise. See honeycomb-shaped floor parts ref. to DE 3809185 C2 made of *paper* to dampen road noise.

VIII. Passing the strict EU- and US- side crash tests with a few modifications of the vehicle floor of a prototype or production model. The modifications of MB A "AC" into a compact car "GO" substantiate the applicability of the deformable elements for any vehicle floor.

IX. Costs cut by standardizing the deformable elements with arbitrary cross section and contour for vehicles of different classes, by minimizing the number of the types and/or by employing a single deformable element **1 (Fig.** 33).

X. Inexpensive design, low manufacturing costs, high reliability, low reject rate and saving labour-time thanks to simple assembly, disassembly and repair.

BRIEF DESCRIPTION OF THE DRAWINGS

A number of embodiments, other advantages and features of the present invention of motor vehicle will be described in the accompanying drawings with reference to the xyz global coordinate system:

Fig. 1 is a schematic perspective view of the 1st embodiment of a vehicle floor of a compact car "GO", an energy-absorbing improvement over the vehicle floor of a prototype MB A ® of **Fig.** 2a and 3a, equipped with five elements deformable under the imposition of impact force **X, Y** or **X1** in the event of front, side or rear collision or pile up.

Fig. 2 is a bottom plan view of the 1st embodiment of the vehicle floor in yz plane.

Fig. 2a is a bottom plan view of the vehicle floor of the MB A ® "AC", ref. to US 5,464,266 (DE 4326270 A1) and DE 4326269 C1, in yz plane comprising two runners, side rails, bumpers, an A-, B-, C-cross member, a front deformable element and four impact elements under the imposition of impact force **X** or **Y** in the event of front or side collision.

Fig. 3 is a cross-sectional view of the 1st embodiment of the vehicle floor along the line II-II of **Fig.** 2.

Fig. 3a is a cross-sectional view of the MB A "AC" along the line II-II of **Fig.** 2a.

Fig. 4 is a partially enlarged cross-sectional view of **Fig.** 3.

Fig. 5 is a cross-sectional view of a vehicle door and a side deformable element with a ledge serving as a step rail along the line II-II of **Fig.** 2.

Fig. 6 is a perspective view of the side deformable element having a ledge.

Fig. 7 is a cross-sectional view of a shearable bolt of the side deformable element in engagement with the mating hole of a piece along the line I-I of **Fig.** 4.

Fig. 8 is a cross-sectional view of a shearable pin engaging with the side deformable element.

Fig. 9 is a cross-sectional view of the side-end portion of the deformable element bolted to the C-cross member along the line III-III of **Fig.** 2.

Fig. 10 is a schematic perspective view of the 1st embodiment of a deformable element subdivided into crumpling zones provided with sites of predetermined fracture, engaging points and/or honeycomb-shaped energy-absorbing members.

Fig. 11 is a perspective view of the 2nd embodiment of a deformable element of varying stiffness and an additional deformable element of longitudinally varying stiffness.

Figs. 12 to 14 are perspective views of the respective 3rd to 5th embodiment of a deformable element having an outer or inner guide tube to receive a round auxiliary tube.

Fig. 15 is a perspective view of the 6th embodiment of a deformable element in a form-locking connection with a mating deformable element via the 1st embodiment of interengaging assemblies distributed along the upper and lower region thereof at one assembling side.

Fig. 16 is a perspective view of the 7th embodiment of the deformable elements of **Fig.** 15 provided with the 2nd embodiment of interengaging assemblies.

Fig. 17 is a perspective view of the 8th embodiment of the deformable elements of **Fig.** 15 provided with the 3rd embodiment of interengaging assemblies.

Fig. 18 is a perspective view of the 9th embodiment of the deformable element and a mating deformable element, both provided with the 4th embodiment of interengaging assemblies.

Fig. 19 is a cross-sectional view of the 1st embodiment of a deformable element of the trunk compartment, in form-locking connection with the rear portions and wheel cases, and storage rooms along the line V-V of **Fig.** 2.

Fig. 20 is a partially enlarged cross-sectional view of **Fig.** 19 to illustrate the honeycomb-shaped energy-absorbing members, engaging pin and hinge.

Fig. 21 is a top view of the 2nd embodiment of a half of a deformable element of the trunk compartment in form-locking connection with the rear portion, engaging rail and wheel case.

Fig. 22 is a perspective view of the process to form-locking connect the members of the deformable element of **Fig.** 21 to each other and to the respective frame members.

Fig. 23 is a schematic perspective view of the 2nd embodiment of a vehicle floor comprising open cross sectional frame members to receive deformable elements and bearing boxes.

Fig. 24 is a schematic perspective view of the 3rd embodiment of a vehicle floor comprising open cross sectional frame members to receive deformable elements and bearing boxes.

Fig. 25 is a perspective view of a bearing box and its parts.

Figs. 26 to 28 are front views of the 1st to 3rd embodiment of an open cross sectional runner in form- and force-locking connection with a bearing box.

Figs. 29 to 30 are bottom plan views of the 4th to 5th embodiment of a vehicle floor having at least one leaf spring serving as a deformable element.

Fig. 31 is a bottom plan view of the 6th embodiment of a vehicle floor provided with the respective deformable elements for energy absorption in arbitrary collision.

Fig. 32 is a bottom plan view of the 3rd embodiment of the vehicle floor of **Fig.** 24 provided with the respective deformable elements for energy absorption in arbitrary collision.

Fig. 33 is a bottom plan view of the 7th embodiment of a vehicle floor provided with the respective deformable elements for energy absorption in arbitrary collision.

Fig. 34 is a perspective view of two mechanisms ref. to DE 4406129 A1 under load of front- or rear impact force.

Fig. 35 is a cross-sectional view of a half of the vehicle and two connecting rods in a channel along the line VI-VI of **Fig.** 34.

Figs. 36 to 38 are schematic views of a safety device ref. to DE-OS 2225481 under load of impact forces in zy-, zx- and xy-plane.

Figs. 39 and 40 are top plan views of two similar cars rotated at the same angle about the vertical axis of the mutual point of collision in a 50 % offset crash test.

Figs. 41 and 42 are top plan views of two cars with different weights in an approx. 50 % offset crash test.

Fig. 43 is a top plan view of two cars in a real accident.

Fig. 44 is a top plan view of a safety device ref. to US 5,911,426 and 5,921,578.

Fig. 45 is a top plan view of the safety device of **Fig.** 44 when the tires of the car hit the curbstone of a pavement.

As customary, the use of (not shown) sealing parts against dirt and water is highly recommended for the purpose of securing the function of the piston device, however, not shown for the sake of perspicuity.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Beyond doubt, the function of the deformable elements is well described in the preferred embodiments of the prior art. However, the applicability thereof would become apparent in the scope if the explanation of how to assemble the deformable elements to the vehicle frame in reference to the **Figs.** would be included. When the assembly process is known, the costs and time can be estimated. Hence, this subject must be taken into account when the function and assembly thereof is described in conjunction with manufacturing parts thereof and absorbing large energy in the event of arbitrary collision.

The right-hand drive vehicle is represented by the steering wheel **81** drawn with dotted heavy lines (**Fig.** 3), the position of each pillar and cross member in all **Figs.** by the capital letters A, B and C (**Figs.** 2, 31). It is to be clearly understood that the features are applicable for any vehicle with an arbitrary number of pillars and cross members, accordingly for any vehicle floor. The driving direction shown in all **Figs.** is opposite to the x-direction of the xyz global coordinate system illustrated **Figs.** 1 to 3, 10, 15, 19, 31.

With the exception of the detachable deformable elements **3** and **3a** serving as a releasable floor of the trunk compartment the deformable elements are housed in the vehicle floor or under the vehicle floor **57** (**Figs.** 3a). By applying the associative rule the parts of each interengaging assembly can be arranged to the mutual deformable elements in either way **1** *and* **2** or **2** *and* **1** (**Figs.** 15 to 18, 32 to 33).

In analogy to the principle of *"piston engine"* to perform work, the piston **1.2** guided by the bearing box "compresses" or deforms the *deformable element* (**Figs.** 1, 2, 10, 31 to 33) under load of impact force in the event of collision against the barrier **80** (**Fig.** 3a) or the opposite vehicle (**Figs.** 39, 41, 43). Due to the constant stiffness of the crumpling zones of longitudinal runner e.g. ref. to US 5,480,189, US 3,860,258 the total energy absorption occurs *abruptly and immediately* despite the proposal for controllable folding and buckling thus making a control of the rate of deceleration impossible. In order to ensure a time-dependent curve of acceleration (deceleration) lower than the threshold value of severe/fatal injury during the collision, large-area (proper term: large-volume) deformable elements with controllable deformation behaviour are required. Any deformable element having an *arbitrary* cross section and contour is subdivided into a number of crumpling zones $\mathbf{Z_1}$, $\mathbf{Z_2}$,

Z_3, Z_4,.. Z_{n+1} with sites of predetermined fracture (**Figs.** 10, 12, 16, 18, 21). Controllable deformation behaviour is determined by inequal stiffness of crumpling zones in juxtaposition having *different peak stresses* under load. However, they may have peak stresses at the same level as long as their crumpling zones e.g. Z_2 and Z_{10} are not in juxtaposition. The transient times to the yield value (fracture stress) are variable, hence, determinable by the **design features** of stiffness-varying crumpling zones in the 1st to 9th embodiment of a deformable element:

1) *number and/or inequal distances of sites* ref. to **G1** (design-features-type **1**) such as welding spots (**Fig.** 10), transition sites (engaging points) P_1, P_2, P_3, ... , P_n (**Figs.** 16 to 18) or assembling points R_1, R_2, R_3, ... , R_n (**Figs.** 24, 32);
2) *sites of predetermined fracture* such as recesses, oblong holes ref. to **G2**, holes ref. to **G2a**, cut-off in welded area ref. to **G2b**, rounded cut-off in welded area ref. to **G2c**, cracks ref. to **G3** or corrugations ref. to **G4**. The juxtaposed crumpling zones of a deformable element can be separated by a transition area defined by recesses ref. to **G9** (**Figs.** 12, 13). To prevent from buckling laterally the deformable element is provided with at least one guide tube **1.8a**, formed by two half-rings (**Fig.** 14), or with at least one guide tube **1.8** (**Figs.** 12, 13), wherein an auxiliary tube **60b, 60c, 60c1, 60c2** (**Figs.** 31 to 33) is inserted to guide the deformable element during energy absorption and to prevent lateral buckling thereof.
3) *honeycomb-shaped energy-absorbing members* ref. to **G5** like deformable element **2** illustrated partially (**Fig.** 1), deformable element **1** (**Fig.** 10) and deformable members **3.1, 3.2** (**Fig.** 20);
4) *integrating additional part thereon or therein* ref. to **G6**;
5) *longitudinally varied stiffness of a deformable element* **1a** with angle α (**Fig.** 11) ref. to **G7**;
6) *integrating an additional deformable element* **1z** *of varying stiffness therein* ref. to **G8** (**Fig.** 11);
7) *multi-leaf spring as deformable element* ref. to **G10**, e.g. three leaves, mounted laterally (**Fig.** 29) or longitudinally (**Fig.** 30). In dependence on cracks, holes ("b" is a hole of the spring element **21** (**Fig.** 5)), different radii of curvature of leaves and/or different thickness the sites of predetermined fracture can be pre-calculated by FEM, hence, varied [1 to 3]. Moreover, other materials with the properties of high-energy absorption and small mass, e.g. used for skis, like carbon/glass fibre-reinforced plastics are recommended for use.
8) *interconnection of the first deformable element **1e, 1f**, responsible for energy absorption in front- or rear collision, and the second deformable element **2b** to **2e**, responsible for energy absorption in side collision, by interengaging assemblies* ref. to **G11** (**Figs.** 15 to 18) increases the energy-absorbing masses in any collision. The stiffness of the transition area of juxtaposed crumpling zones is weakened by L- or T- (spade-) shaped oblong holes or recesses. Parts of deformable element are fabricated and formed by shallow drawing, extruding, welding, bolting, riveting and/or glueing. The deformable element **1** with struts (**Fig.** 10) is formed either by welding four sheet metals (panels) **1.10, 1.11** together or from light weight material by extrusion. Finally, the recesses of the deformable element **1f** are machined to serve as sites of predetermined fracture and to receive the engaging pins **2.1b** (**Fig.** 18).

It is obvious that the lateral buckling of the deformable element can be prevented and the deformation behaviour thereof can be controlled by different peak stresses of juxtaposed crumpling zones and the mutual direction of the deformation of all the crumpling zones and the movement of the piston **1.2** (**Fig.** 10).
To cut costs a single deformable element **1** (**Fig.** 31) is designed in association with the above-mentioned design features to define the sections each of which is responsible for energy absorption in the event of front, side or rear collision.

The 1st to 4th embodiment of the interengaging assemblies determines the crumpling zones of the first and second deformable element **1e, 1f, 2b to 2e**. The insertion of the mating parts of interengaging assemblies makes the assembly of the second deformable element to the first deformable element easier thus saving costs and time.
Ref. to **Fig.** 15 the interengaging assemblies consist of upper and lower engaging pins **1.15** distributed on the respective upper and lower transition areas of juxtaposed crumpling zones of the first deformable element **1e** in x-direction and the mating L-shaped oblong holes, distributed along both legs of the U-shaped portion of the second deformable element **2b**, serving as upper and lower transition sites of juxtaposed crumpling zones thereof. Both deformable elements are interconnected upon the insertion of the mating L-shaped oblong holes into the upper and lower engaging pins in y-direction, which are secured in the U-forms of the mating L-shaped oblong holes by the movement of the second deformable element in x-direction. If necessary, a welding spot like transition site "P_1 to P_n" ensures a rigid connection of both elements to each other (**Fig.** 17).
Ref. to **Fig.** 16 the interengaging assemblies consist of upper and lower engaging pins **1.15** distributed on the respective upper and lower transition areas of juxtaposed crumpling zones of the first deformable element **1e** in x-direction and the mating T-shaped oblong holes, distributed along both legs of the U-shaped portion of the second deformable element **2c**, serving as upper and lower transition sites of juxtaposed crumpling zones thereof. Both deformable elements are interconnected upon the insertion of the mating T-shaped oblong holes into the upper and lower engaging pins in y-direction, which are secured in the U-forms of the mating T-shaped oblong holes by the movement of the second deformable element in x-direction. If necessary, a welding spot like transition site "P_1 to P_n" ensures a rigid connection of both elements to each other (**Fig.** 17).
Ref. to **Fig.** 17 the interengaging assemblies consist of engaging pins **1.15** distributed on the upper transition areas of juxtaposed crumpling zones of the first deformable element **1e** in x-direction and the mating T-shaped oblong holes, distributed along the upper leg of the U-shaped portion of the second deformable element **2d**, serving as transition sites of juxtaposed crumpling zones thereof. Both deformable elements are interconnected upon the insertion of the mating T-shaped oblong holes into the engaging pins in y-direction, which are secured in the U-forms of the mating T-shaped oblong holes by the movement of the second deformable element in x-direction. The transition sites "P_1 to P_n" of the lower leg of the U-shaped portion of the second deformable element are welded, bolted or glued to the mating sites of the lower transition areas of juxtaposed crumpling zones of the first deformable element.

Ref. to **Fig.** 18 the interengaging assemblies consist of engaging pins **2.1b**, both ends of which are attached to both legs of the U-shaped portion of the second deformable element **2e**, serving as transition sites of juxtaposed crumpling zones of the second deformable element **2e** and the mating recesses of the first deformable element **1f**, each of which is on one engaging side of a transition area between the juxtaposed crumpling zones provided with guide tubes in the common axis. The corresponding crumpling zones of both deformable elements are interconnected when the engaging pins are inserted into the mating recesses and secured therein by an auxiliary tube **60c** projected through the guide tubes of all the crumpling zones in the common axis.

In analogy to "*guiding a piston rod of an engine*" the *piston rod* must be guided in the 1st to 3rd embodiment of a bearing box attached to or in the portion of a runner.

1) by the sleeve bearings (not shown) in the bearing box attached to the front portion **30.1** of a runner and/or of the A-cross member **31** ref. to **F1** (guidance-type 1) (**Figs.** 1 to 2). This feature can be applied for the attachment to the rear portion of a runner (**Fig.** 32);
2) by the sleeve bearings (not shown) in the bearing box **30.7, 30.7a** form- and force-locking connected to the runner **30a, 30a1** ref. to **F2** (**Figs.** 25, 26, 29 to 31). The bearing box **30.7, 30.7a** is assembled by positioning and bolting both engaging plates **30.6** to the corresponding guide plates **30.5** via guide pins **30.4** (**Fig.** 25); or
3) by a bore of the bearing box **30.7, 30.7b, 30.7c** made of an extrusion component fabricated from light material, the engaging receptacles of which are plug-in (form-locking) and force-locking connected to the mating parts of the runner **30a, 30a1, 30a2** ref. to **F3** (**Figs.** 27, 28). To save costs the extrusion process is further exploited to manufacture a number of bores of the bearing box **30.7c**, e.g. three bores and the fourth drawn with dotted lines, to guide several piston rods (**Figs.** 32, 33) and receive auxiliary members such as tubes **60c, 60c1, 60c2**.

The cross section of piston rod is arbitrary, however preferably round or rectangular because of the low manufacturing costs. Owing to the space saving design the piston rods can be arbitrarily arranged in the front and/or rear section of the vehicle body.

Generally, a piston device includes at least one piston rod **5.2**,

- one end of which is fastened to the bumper with sites of predetermined fracture or to an impact pan **5.1**, which is located adjacent to the conventional bumper, and
- the other is fastened to a piston **1.2**, which is rigidly connected to the deformable element or spaced at a distance of "l0" thereto (**Figs.** 31, 33). When the piston rod is equipped with a coil spring **4d** or rubber spring **4c**, it telescopes further into the bearing box within the distance of "l0" to store minor energy when the bumper is loaded and to return the bumper to the home position when the bumper is unloaded.

A pair of independently operating front piston devices includes a pair of front *double* bearing boxes **30.7**, connected to the front portions of longitudinal runners according to **F3**, and a pair of front pistons **1.2**, fastened to the front-end portions **1.1** of the front deformable elements **1** (**Fig.** 32).

A pair of independently operating front piston devices includes a pair of front *twin* bearing boxes **30.7**, connected to the front portions of longitudinal runners according to **F3**, and a pair of front pistons **1.2**, fastened to the front-end portion **1.1** of the single deformable element **1** (**Fig.** 33).

A pair of independently operating rear piston devices includes a pair of rear *twin* bearing boxes **30.7**, connected to the rear portions of longitudinal runners according to **F3**, and a pair of rear pistons **1.2**, spaced at a distance of "l0" to the rear-end portion **1.1** of the single deformable element **1** (**Fig.** 33).

Ref. to **Figs.** 1 to 9 the 1st embodiment of a vehicle floor of the compact car "GO", substantially safer than the compact car "AC" shown in **Figs.** 2a, 3a, comprises two bumpers **35, 36** and

- two runners **30**, each of which is subdivided into a rectangular front portion **30.1**, a U-shaped central portion **30.2** (**Fig.** 4) and a rectangular rear portion **30.3**;
- an A-cross member **31**, subdivided into two U-shaped side transverse portions (torsional boxes) **31.1** and a rectangular central transverse portion **31.2**;
- a C-cross member **33**, subdivided into two U-shaped side transverse portions (torsional boxes) **33.1** and an U-shaped and rectangular central transverse portion **33.2** (**Fig.** 9);
- a B-cross member **32**;
- a double U-shaped tunnel rail **60**, welded to all cross members and
- at least one pair of independently operating piston devices, above-mentioned.

Each deformable element **1** of four panels **1.10, 1.11**, provided with soundproofing strips **1.7**, is inserted into the space, defined by the half of double U-shaped tunnel rail **60** and the U-shaped central portion **30.2** (**Fig.** 4). The plate **1.1** of the rear-end portion thereof is secured to the central portion of C-cross member by bolts **1.12** (**Fig.** 9). The plate **1.1** of the front-end portion thereof is bolted to the piston **1.2** of the piston device by bolts **1.5** (**Fig.** 10). Subsequently, the auxiliary plate **6** is secured to the central portion of C-cross member by coupling elements **6.2, 6.7** (**Fig.** 4). The side deformable element **2** with soundproofing strips **2.7**, projected into the U-shaped side transverse portion **31.1** and transverse portion **33.1**, is secured to the auxiliary plate **6**, serving as a fixture by coupling elements **6.1, 6.6** and to the side rail **34** by shearable bolts **2.1** and/or shearable pins **2.1a** with the mating holes of pieces **2.4** of the side rail **34** provided with sound-proofing pieces **2.3** (**Figs.** 4, 7). Under load of the weight of side deformable element **2, 2a** and, particularly, the weight of passenger, standing on the step rail **2.8**, the defection of the element **2, 2a** spoils the overall stylish impression. Doubtless, it is not beneficial to sales. There is a need for a height-adjusting mechanism. To adjust the height a tool is inserted through the overlapping holes of side rail **34** into a hexagon socket head of shearable bolt **2.1** (**Figs.** 4, 7). The number of shearable bolts and/or shearable pins arranged longitudinally and/or transversely depends on the width, length, weight of the deformable element and the weight of passenger standing on the step rail. In excess of the predetermined force in a side collision the shearable parts **2.1, 2.1a** and/or the mating pieces **2.4** with thickness, "a" denoted in **Fig.** 7, are broken or shorn so that the crumpling zones will be fully exploited to absorb energy. Substituting the shearable parts with welding spots cuts the manufacturing cost, but the repair cost will increase. The flat B-cross member **32** can be replaced by an open cross sectional intermediate cross member **32c**, similar to **30a** (**Figs.** 23, 24, 33).

Ref. to **Fig.** 23, 24 and 32 the 2nd to 3rd embodiment of a vehicle floor comprises at least one bumper **35, 36** and

- a pair of open cross sectional runners **30a** and a pair of open cross sectional side rails **34a**;
- a pair of U-shaped tunnel rails **60e**, providing a space below the vehicle floor to house any part of power plant such as

* an exhaust pipe of a rear wheel drive vehicle and a drive shaft or
* an exhaust pipe of a front wheel drive vehicle;

– three closed cross sectional cross member **31a to 33a, 31b to 33b**, rigidly connected to the runners **30a**, tunnel rails **60e** and side rails **34a**; and
– at least one pair of the above-mentioned, independently operating piston devices.

Each of the two pairs of deformable elements **1** (**Fig.** 32) is projected through the open cross sectional side rails **34a** and the open cross sectional central portions of runners **30a** into the U-shaped tunnel rail **60e**. Either two pairs or one pair of side deformable elements **2a1, 2a2, 2a3** are projected through the respective open cross sectional portions of side rails **34a** into the respective side portions of deformable elements **1** in juxtaposition. Each side deformable element has step rail **2.8** (**Fig.** 6). Regarding the 2nd embodiment the three cross member **31a to 33a** are provided with assembling bores "b_1 to b_{an}" at the side region and "e_1 to e_n" at the central region in common axes to receive and to secure at least two pairs of auxiliary tubes **60b, 60c, 60c1, 60c2**, when projected therethrough and through the deformable elements **1** and the side deformable elements **2a1, 2a2, 2a3**. When the auxiliary tube **60b, 60c** is too long for projection, it is replaced by two short auxiliary tubes **60c1, 60c2** or by auxiliary plates (**Figs.** 23, 24, 32).

Regarding the 3rd embodiment the three cross member **31b to 33b** are provided with the respective auxiliary plates **31.5 to 33.5** at the side region and a pair of auxiliary plates **32.6** at the central region of cross member **32b**. The deformable elements **1** and the side deformable elements **2a1, 2a2, 2a3** are fastened to the assembling points $\mathbf{R_1, R_2, R_3, \ldots, R_n}$ of the respective auxiliary plates **31.5 to 33.5** and the assembling points $\mathbf{Q_1, Q_2, Q_3, \ldots, Q_n}$ of auxiliary plates **32.6** (**Fig.** 24).

Ref. to **Fig.** 29 the 4th embodiment of a vehicle floor, each of two multi-leaf springs **4a** ref. to **G10**, serving as a deformable element **1**, is transversely mounted to the A-cross member **31a**. For example this multi-leaf spring comprises three leaves **B1, B2, B3**. To protect passengers in a rear collision another multi-leaf spring can transversely be mounted to the C-cross member **33a**.

Ref. to **Fig.** 30 the 5th embodiment of a vehicle floor, a multi-leaf spring **4b** ref. to **G10**, serving as a deformable element **1**, guided by the open cross sectional runner **30a** is longitudinally mounted to a stiff member **60a** on each vehicle side to protect passengers in a front or rear collision.

Ref. to **Fig.** 31 the 6th embodiment of a vehicle floor comprises two bumpers **35, 36** and

– a pair of open cross sectional runners **30a** and a pair of open cross sectional side rails **34a**;
– an open cross sectional tunnel rail **60d**,
– three closed cross sectional cross member **31a, 32c, 33a**, rigidly connected to the runners **30a**, tunnel rail **60d** and side rails **34a** and provided with bores in the common axes;
– at least one pair of the above-mentioned, independently operating piston devices, equipped with a pair of springs **4d** and
– an energy-absorbing assembly for a trunk compartment (**Fig.** 19), undermentioned, or a deformable floor **3c**, fastened to both rear portions of longitudinal runners **30a** and the rear cross member **33a**.

A single deformable element **1**, inserted between the front **31a** and rear cross member **33a**, through the side rails **34a**, longitudinal runners **30a**, tunnel rail **60d** and intermediate cross member **32c**, is in abutting relationship to both vehicle sides and secured by two pairs of auxiliary tubes **60c**, projected therethrough and through the bores of front and rear cross member in the common axes and fastened to the front and rear cross member.
The deformable element, the rear-end portion of which is fastened to the rear cross member,
- absorbs impact energy in any front collision while moving along the auxiliary tubes; or
- is deformed at the side portion in any side collision.

Ref. to **Fig.** 33 the 7th embodiment of a vehicle, having the same vehicle frame as the 6th embodiment, is provided with a pair of the above-mentioned, independently operating front twin piston devices and a pair of the above-mentioned, independently operating rear twin piston devices.
A single deformable element **1**, inserted between the front **31a** and rear cross member **33a**, through the side rails **34**, longitudinal runners **30a**, tunnel rail **60d** and intermediate cross member **32c**, is in abutting relationship to both vehicle sides and secured by a pair of auxiliary tubes **60b**, projected therethrough and through the bores of front and rear cross member in the common axes and fastened to the intermediate member.
The deformable element, fastened to the intermediate cross member **32c**,
- absorbs impact energy in any front collision while moving along the auxiliary tubes; or
- is deformed at the side portion in any side collision.

Ref. to **Figs.** 1, 2, 19, 20 the 1st embodiment of a rear deformable element **3** of the trunk compartment comprises a central deformable member **3.1** and a pair of side deformable members **3.2** pivotally connected thereto with hinges **3.3**. Rooms between the detachable deformable element **3, 3a**, the rear wall of the passenger compartment, the rear wall of rear bumper **36**, both wheel cases **40**, both rear portions **30.3** and the lower floor of the trunk compartment can be used for storage. The engaging pins **3.5** of the deformable member **3.1** are longitudinally arranged parallel to the mating holes of the rear portions **30.3**, distance "T" indicated in **Fig.** 19. The length of deformable element **3** almost equals the depth of trunk compartment.
The detachable deformable element **3, 3a**, serving as the upper floor of the trunk compartment, is in form-locking connection with the pair of rear portions of longitudinal runners and both rear wheel cases **40**, in abutting relationship to the rear cross member **33** and the rear wall (not drawn) of rear bumper **36** as well as being releasable therefrom (**Figs.** 1, 21).
By means of both hand grips **3.4** of the deformable members **3.2**, folded up, the engaging pins **3.5**, drawn with dotted lines (**Fig.** 19), of deformable member **3.1**, resting on the rear portions, are placed adjacent to the mating holes (**Fig.** 1). Because the diameter of the head of each engaging pin is a little smaller than the sidelong width of each mating hole, the sidelong hand movement illustrated by arrow and "S" (**Fig.** 19) moves all engaging pins into the mating holes for the purpose of form-locking connection. When folded down, the deformable members **3.2** cover both storage rooms "SL" and "SR",
- the lateral surface of each deformable member **3.2**, having engaging holes, is in form-locking connection with the C-shaped rear wheel case **40**, whereto mating pins **40.1** are rigidly attached; and
- the holes engage with the mating pins **40.1**.

The number of the interengaging assemblies engaging pins / mating holes, e.g. five, determines the number, e.g. six, of crumpling zones of the deformable element **3** (**Figs.** 1 and 21).

Ref. to **Figs.** 21, 22 the 2nd embodiment of a deformable element **3a** of the trunk compartment comprises a central deformable member **3.1a** and a pair of side deformable members **3.2a**. The design parameters of this embodiment without hinges **3.3** such as distances, lengths, shapes etc. are similar to the 1st embodiment.
The deformable member **3.1a** is provided with two rows of the engaging pins **3.5a** to engage with the mating holes of both rear portions **30.3**. The number of the interengaging assemblies engaging pins / mating holes determines the number of crumpling zones $\mathbf{Z_1}$, $\mathbf{Z_2}$, $\mathbf{Z_3}$, $\mathbf{Z_4}$,.. $\mathbf{Z_6}$ of the deformable element **3a** in direction of impact force **X1**. The crumpling zones in both directions of impact forces **X1** and **Y** will be defined, when the deformable member **3.1a** is additionally provided with a transverse guide beam **3.8**, having engaging pins **3.7** which engage with the mating holes of the cross rail **3.9** rigidly attached to the C-transverse portion **33.2** of the cross member, thus optimizing the deformation behaviour of the deformable element **3a**.
The schema illustrated by arrows (**Fig.** 22) shows the form-locking connection of all engaging pins **3.5a**, **3.7** to the mating holes of both rear portions and of that cross rail along which the inner edge of the guide beam **3.8** slides. Additional costs will be incurred only for manufacturing and assembly of parts **3.8**, **3.9** due to preserving the distances of the corresponding interengaging assemblies thereof.
When lowered down, each deformable member **3.2a** covers a storage room "SL" or "SR" and is in form-locking connection of
- its lateral surface to the C-shaped rear wheel case **40**;
- its engaging holes to the mating pins **40.1**, rigidly attached to the wheel case **40** and
- its engaging pins **3.6a** to the mating holes of rear portion **30.3** and recesses of deformable member **3.1a**.

Ref. to **Fig.** 31 the 3rd embodiment of a deformable element **3c** of the trunk compartment is in form- and/or force-locking connection with both rear portions **30.3** of the runners **30a** and/or the C-cross member **33a** via interengaging assemblies, similar to those of the deformable element **3**, **3a**, welding and/or bolting. The deformable element **3c** can serve as a lower floor of storage rooms, shown in **Fig.** 19.

Although the present invention has been described and illustrated in detail, it is clearly understood that the terminology used is intended to describe rather than limit. Many more objects, embodiments, features and variations of the present invention are possible in light of the above-mentioned teachings. Therefore, within the spirit and scope of the appended claims, the present invention may be practised otherwise than as specifically described and illustrated.